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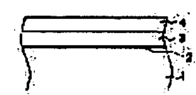
(54) PROJECTION EXPOSURE METHOD

(57)Abstract:
PROBLEM TO BE SOLVED: To form a smaller microscopic pattern by a method wherein the partial coherent coefficients, which correspond to those of circular secondary light sources having outer and inner diameters equal to those of torus-shaped secondary light sources, of the torus-shaped secondary light sources are set at a value within a specified range, the reflectance of exposure light from a substrate to be exposed is set at a specified one or lower and the film thickness of a resist is formed in a thickness of the value or lower of a specified formula.



SOLUTION: An antireflection film 3 is formed on a silicon wafer 1, which is mirror-finished, so that the reflectance of exposure rays is 0.5% or lower and a resist film 4 is formed on this film 3 in a thickness of 3.λ/(2n) or thinner. Here, the (λ) is assumed an exposure wavelength and the (n) is assumed the refractive index of the resist film. Therefore, the resolution of the resist film can be significantly enhanced. Here, by using torus-shaped secondary light sources, which have the mean value (σm) of the partial coherent coefficients to correspond to those of circular secondary light sources having outer and inner diameters equal to those of the torus-shaped secondary light sources within the range of 0.61 to 0.73 and have the value (Δσ) of 1/2 of the difference between their coherent coefficients within the range of 0.05 to 0.15, in combination with each other, a high-resolution pattern transfer can be made even in a low contrast of about 0.4.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] Projection exposure is carried out at the resist which formed the pattern on an original-drawing substrate on the exposed substrate through the projection optical system, and this invention relates to the projection exposure method which forms the resist pattern corresponding to the pattern on an original-drawing substrate through development etc. in order to form detailed patterns, such as a semiconductor integrated circuit.
[0002]
[Description of the Prior Art] Projection dew using the projection aligner in order to imprint the detailed pattern on original-drawing substrates, such as a reticle and a mask, on exposed substrates, such as a semiconductor wafer Drawing 9 is the block diagram of the conventional typical projection aligner. A mercury lamp, an excimer laser, solid state laser, etc. are used for this conventional kind of projection aligner as the primary light source. In drawing 9 , the case where a mercury lamp was used as the primary light source was shown as an example of representation, the light from a mercury lamp 15 was condensed by the ellipse mirror 16, the flux of light was operated orthopedically, and the condensing optical system 17 which becomes an optical axis from a lens, a mirror, etc. of the plurality mostly made parallel or the singular number is led to the eye lens 18 of through and a fly.
[0003] The reflective mirror 19 is bearing the duty which is passed to exposure, and makes and removes an unnecessary heat ray to it, without if possible reflecting while it changes the direction of an exposure beam of light and makes equipment compact. Prism may be used instead of a mirror. In drawing 9 , although only one reflective mirror 19 was drawn, since two or more sheets are used, an optical path is bent arbitrarily. When using an excimer laser, solid state laser, etc. as the primary light source, the optical system which extends the flux of light and is led to the eye lens 18 of a fly with a lens is used in many cases. Moreover, the optical element changed into wavelength, such as a double cycle and a 4 time cycle, may intervene. In addition, in drawing 9 , 20 is a filter which penetrates only predetermined wavelength, in order to attain single wavelength-ization.
[0004] The eye lens 18 of a fly is the aggregate of the diameter lens of a small sum. This condenses with the condensing optical system 22a and 22b which consists of a lens etc., and it is made to make an exposure beam of light superimpose so that the injection light from each diameter lens of a small sum to constitute may cover and illuminate the whole region of the exposure field of the original-drawing substrate 21 respectively. By this, it is the structure which raises the homogeneity of lighting. The reflective mirror 23 is for changing the direction of an exposure beam of light, and making equipment compact. The duty which exposure is made to pass an unnecessary heat ray and is removed like the reflective mirror 19 may be given to this. Moreover, since two or more reflective mirrors 23 are used, an optical path can change a direction arbitrarily.
[0005] In addition, an optical fiber bundle may be used instead of the eye lens 18 of a fly. Moreover, combination, such as prism, a lens, and a mirror, once divides into some the light which comes out of the primary light source, the divided flux of light may be made to superimpose on the original-drawing substrate 21, and the homogeneity of lighting may be raised. Moreover, the eye lens and optical fiber bundle of another fly may be placed before the eye lens 18 of the fly which finally carries out superposition lighting of the original-drawing substrate 21, or an optical fiber bundle, or the eye lens of a fly, an optical fiber bundle, and other flux of light division and a superposition means may be used together.
[0006] And since the outlet of the light which carries out superposition lighting of the original-drawing substrate 21 equivalent to the injection mouth of the eye lens 18 of a fly serves as the apparent light source which illuminates the original-drawing substrate 21, it is called secondary light source. The method of specifying the configuration of this secondary light source is arbitrary. In usual, it makes it possible to arrange the drawing 24 of the fixation for controlling the size and configuration of the secondary light source, the size adjustable, or exchangeable structure near the injection mouth of the eye lens 18 of a fly, and to acquire arbitrary configurations easily. Moreover, the image of the secondary light source is formed at once between the eye lens 18 of a fly, and the original-drawing substrate 21, it extracts to the position, and 24 is arranged in many cases.
[0007] The original-drawing substrate 21 has the pattern which consists of a shading object, a halftone shading object, phase shifters, or those arbitrary combination, such as chromium, on the substrate of light-transmission nature, such as a quartz and glass. Of the light which illuminates this original-drawing substrate 21, the pattern image of the original-drawing substrate 21 is formed in the surface position of the exposed substrate 26 through a projection optical system 25. As a projection optical

system 25, what combined the projection lens, or a mirror and a lens is used. The aperture diaphragm 27 which specifies the passage range of the beam of light which reaches the exposed substrate 26 is put on a part of projection optical system 25.
[0008] By drawing 9 , the projection optical system 25 which used the projection lens is drawn typically, and signs 28 and 29 show the lens group in a projection lens. If the exposed substrate 26 in which the resist film was formed on the front face is arranged and the original-drawing substrate 21 is illuminated, the light figure corresponding to the pattern on the original-drawing substrate 21 will be formed in a resist film front face of a projection optical system 25. By this, a resist exposes according to the strength of an optical distribution of the projection image. If a development is given to this exposed resist film, the pattern of the resist corresponding to the projection image will be formed.
[0009] In the projection aligner for detailed pattern formation, the pattern on the original-drawing substrate 21 is reduced by the projection optical system 25, and it imprints in many cases. In such a case, since having made the size of the exposure field small tends to raise the definition ability of a projection optical system 25, a pattern cannot be formed in many cases at once all over the exposed substrate 26. Therefore, many exposed substrate installation stages 30 on which the exposed substrate 26 is put have the function in which step ANDORE peat is carried out by X-Y stage 31.
[0010] In drawing 9 , the beam of light and beams of light 36 and 37 which beams of light 32-35 come out of a mercury lamp 15, and result in the eye lens 18 of a fly show the example of the beam of light which comes out of the eye lens 18 of a fly, and results in the exposed substrate 26. Moreover, although not illustrated, the relative-position detection for carrying out alignment of the original-drawing substrate 21 and the exposed substrate 26, the controlling mechanism, the focal position detection for doubling the front face of the exposed substrate 26 with the focusing point position of a projection optical system 25, a controlling mechanism, etc. are formed in the projection aligner.
[0011] It is made to form a line and a space pattern in such a projection aligner as a judgment index of the resolution which is the minimum pattern size which can be imprinted in the usual case. For example, the optical intensity distribution of the line formed on the exposed substrate 26 and a space pattern image come to be shown in drawing 10 . In this drawing, a horizontal axis is a position on the exposed substrate 26, and a vertical axis is the optical intensity of a pattern image. The maximal value Imax of the optical intensity-distribution curve 38 of drawing 10 Minimal value Imin It can be easily understood that the light and darkness of the pattern image equivalent to the line section and the space section clarify, so that a difference is large.
[0012] Then, the amount shown by the following formulas (1) as contrast C of an image is defined, and let this be the standard of the visibility of a pattern image.
$C=(Imax-Imin)/(Imax+Imin)$ ... (1)
[0013] The optical intensity-distribution curve 38 (drawing 10) of an image changes according to the configuration and size of the secondary light source which illuminate the numerical aperture and the original-drawing substrate 21 of a projection optical system 25 (drawing 9). Moreover, the front face of the exposed substrate 26 changes by which is far apart from the focusing point position of a projection aligner. On the contrary, if the numerical aperture of a projection optical system 25, the configuration of the secondary light source, and a size are fixed and the amount of defocusing of the exposed substrate to a focusing point position is decided, the optical intensity-distribution curve 38 is determined and the contrast of the projection image in the image surface can be calculated.
[0014] It is dependent on the sensitization property and development property of the resist itself whether by a certain contrast, to the optical intensity distribution which carry out periodic change, a resist pattern resolves to a line and a space pattern, and is obtained. For example, if the resist of a property as shown below is used, even if contrast is small, a resist pattern will resolve to a line and a space pattern, and will be obtained. That is, bordering on the light exposure used as a predetermined threshold, a portion with larger light exposure than the threshold exposes, it reacts at the time of development, and the portion with light exposure smaller than the threshold is the resist and the development process that it does not react at all at the time of development.
[0015] However, the dissolution rate to the developer of the exposure section when carrying out wet development of the amount which a resist exposes and reacts at the time of development, for example, the positive form resist, changes gradually according to light exposure rather than changes in stairway bordering on the light exposure used as a threshold. When carrying out wet development of the negative form resist, or when carrying out dry development of the resist of a positive form and one of negative forms, the resist at the time of development can be taken and, as for the direction, changing continuously depending on light exposure is common. If the processing conditions over a resist are fixed, the side attachment wall of the pattern cross section in which the case where the cross-section configuration of the resist pattern obtained after development had the larger contrast of a projection image was formed will approach perpendicularly. On the contrary, if the contrast of a projection image is small, inclination will take lessons from a side attachment wall, and a pattern cross-section configuration will tend to become a trapezoid or Yamagata.
[0016] Drawing 11 is the cross section showing qualitatively the relation between the contrast of a pattern image, and the cross-section configuration of a resist pattern. When the contrast of a pattern image is large, as for drawing 11 (a), drawing 11 (b) shows the case where the contrast of a pattern image is small. As for 39 and 40, in this drawing, a resist pattern and 26 are exposed substrates. Like drawing 11 (b), it is hard coming to resolve adjoining patterns in exposure in the state where the inclination angle alpha of a side attachment wall becomes small.
[0017] By the way, according to a present resist and its present used technology, the contrast which can resolve 1 to 1 line and a space pattern to about 0.5-1.2-micrometer thickness is 0.6-0.7. It follows, for example, contrast 0.6 is made into the resolution limit, and if drawing which took contrast for the spatial frequency of a pattern along the vertical axis for the

horizontal axis is drawn, the spatial frequency of an intersection with the line which shows the calculation result of the straight line of contrast =0.6 and contrast will give the resolution limit. It mainly depends on the wavelength of an exposure beam of light, and the numerical aperture of a projection optical system 25 (drawing 10) for the contrast of the projection image formed of projection exposure. However, even if it fixes these, the contrast of a projection image changes with the configurations and sizes of the secondary light source considerably.

[0018] It is there, next the relation between the configuration of the secondary light source, a size, and a pattern image contrast is described. Below, wavelength of an exposure beam of light is set to lambda, and numerical aperture of a projection optical system 25 is set to NA. Drawing 12 is the block diagram showing the relation between the lighting beam of light from the secondary light source, and the incident ray to a projection lens. As shown in this drawing, the beam of light which carries out incidence to the original-drawing substrate 21, and the beam of light injected from the original-drawing substrate 21 are considered.

[0019] In this drawing, the injection beam of light of the maximum inclination with which beams of light 41 and 42 can enter into the incident ray of the maximum inclination, and beams of light 43 and 44 can enter in the aperture diaphragm 27 of a projection optical system 25 is shown, and a sign 45 is an optical axis. In addition, other signs are the same as that of drawing 9 . When the light which comes out of the half size of the direction range of incidence of the beam of light which irradiates the original-drawing substrate 21 from the point on psi and the original-drawing substrate 21 here sets to phi the half size of the injection direction range which can enter in the aperture diaphragm 27 of a projection optical system 25, numerical aperture in case the numerical aperture when seeing the secondary light source from the original-drawing substrate 21 looks at a projection optical system 25 from sinpsi and the original-drawing substrate 21 is sinphi.

[0020] At this time, partial coherence factor sigma is defined as the following formulas (2) as an amount showing the grade of the partial coherence of an illumination system.

Sigma=sinpsi/sinphi ... (2)

[0021] In the projection aligner by which the image of the secondary light source has come be made in the position of the aperture diaphragm 27 of a projection optical system 25, the following formulas (3) can also show partial coherence factor sigma.

sigma=(radius of secondary light source images in position of aperture diaphragm 27)/(radius of an aperture diaphragm 27) ... (3)

[0022] In addition, a part of lens in a projection optical system 25, monotonous housing, and lens-barrel of a projection optical system 25 may serve as the aperture diaphragm 27. Moreover, the position of the image of the secondary light source may have shifted somewhat, without agreeing in the position of an aperture diaphragm 27 strictly. In this case, suppose that the diameter of opening in the position of the image of the secondary light source is considered the diameter of the aperture diaphragm 27 of the above-mentioned formula (3).

[0023] Moreover, theta, then the numerical aperture NA of a projection optical system 25 are shown by the following formulas (4) in the maximum inclination of an exposure beam of light which reaches the exposed substrate 26.

NA=sintheta ... (4)

In addition, in drawing 12 , beams of light 46 and 47 show the beam of light of the maximum inclination which reaches the exposed substrate 26.

[0024] The relation between the spatial frequency of the 1 to 1 line and the space pattern when making into a parameter partial coherence factor sigma defined above and contrast is shown in drawing 13 . drawing 13 (a) -- the image formation position of a pattern image -- that is, it is the calculated value in focal conditions just Moreover, drawing 13 (b) is calculated value in case the amount of defocusing is D=1.5z.

[0025] In this drawing, in order to separate the influence of the exposure wavelength lambda and the numerical aperture NA of a projection optical system 25, spatial frequency was standardized by NA/lambda. As shown in reference 1 (the 361st page formula of the 12th line of Kubota extensive work "wave optics" (Iwanami Shoten, 1973, the 2nd **) (23-3)), NA/lambda serves as spatial frequency corresponding to the theoretical resolution limit of Leh Leh. Moreover, the amount D of defocusing is z=lambda / 2NA2. It standardized. As shown in reference 2 (the 68th page formula of the 16th line of Toshimasa Tsutsui, Masahide Koyama, and the Yoshinaga ****** "applied optics introduction" (Kanehara & Co., Ltd., Showa 42, reprint) (3.33)), they are z=lambda / 2NA2. It is the value of the theoretical depth of focus.

[0026] In drawing 13 , the horizontal axis is made into spatial frequency and the vertical axis is made into the contrast of a pattern image. If sigma is small, since contrast is high, by the frequency range between low altitudes, a cross-section configuration will turn into a perpendicularly near good configuration. However, a definition [as opposed to / a low sake / a detailed pattern in the contrast of the frequency range between altitude] becomes bad. On the contrary, if sigma is large, in the frequency range between low altitudes, contrast will be low and the inclination of a pattern cross-section side attachment wall will become loose from the case of sigma smallness. However, in the frequency range between altitude, since contrast is higher than the case of sigma smallness, it comes to have possibility that even a detailed pattern will be resolvable.

[0027] If the contrast of a resolvable pattern image is assumed to be 0.6 as mentioned above, a ** value exists in sigma for making the resolution limit high on each defocusing condition. Thus, resolution and resolution are interlocked with and the depth of focus and a pattern cross-section configuration are greatly dependent on the configuration and size of the secondary light source. For this reason, according to a kind, a pattern size, etc. of a pattern which carry out a projection exposure imprint, the equipment which enabled change of the numerical aperture of a projection optical system 25, and the equipment

which enabled it to change the configuration and size of the secondary light source with drawing 24 have appeared.
[0028] furthermore, the configuration of the secondary light source and a size -- the improvement in resolution -- convenience -- good -- making -- "the projection aligner which makes it the feature to have special drawing with which periphery intensity cheats out of the intensity distribution within a injection side of the secondary light source which illuminates a reticle as size from center-section intensity" is indicated by reference 3 (JP,6-82598,B) as technology It will be " if the projection aligner which used special drawing with which periphery intensity cheats out of the intensity distribution within a injection side of the secondary light source which illuminates a reticle as size from center-section intensity according to it is used... A pattern more detailed than before can be formed in a thin resist layer with the deeper depth of focus... It is indicated as ".
[0029] The operation effect of this technology can be explained as follows. The projection exposure (it is called "annulus ring lighting" below) which illuminates the original-drawing substrate 21 with the secondary light source in a circle is considered using special drawing with opening in a circle as drawing 24 (drawing 9). In addition, the projection exposure illuminated with the conventional circular secondary light source calls it "being usually lighting" below. The configuration of the secondary light source of annulus ring lighting is partial coherence factor sigmaout corresponding to the circular secondary light source which has a diameter equal to the outer diameter of the secondary light source. Partial coherence factor sigmain corresponding to the circular secondary light source which has a diameter equal to a bore can express.
[0030] However, the pattern formation property of annulus ring lighting is sigmaout like the after-mentioned. The average and sigmaout of sigmain Parameter sigmam about partial coherence defined by the formula (5) of the following [here], and (6) in order to change corresponding to a difference with sigmain in general deltasigma is introduced.
sigmam = (sigmaout+sigmain)/2 ... (5)
deltasigma= (sigmaout-sigmain)/2 ... (6)
[0031] Partial coherence factor sigma is expressed with the aforementioned formula (3) in the projection aligner by which the image of the secondary light source has come be made in the position of the aperture diaphragm 27 of a projection optical system 25. For this reason, above sigmaout, sigmain, sigmam, and deltasigma correspond to the half width of the circumradius of secondary light source images standardized with a radius of the aperture diaphragm 27 of a projection optical system 25, respectively, an inradius, an average radius, and an annulus ring.
[0032] Hereafter, the diffraction light figure of the secondary light source made in the position of the aperture diaphragm 27 of a projection optical system 25 with the pattern on the original-drawing substrate 21 shown in drawing 12 is considered. Drawing 14 is the plan showing the diffraction light figure of the secondary light source made in the position of the aperture diaphragm 27 of a projection optical system 25 in case 1 to 1 line and the space pattern of the direction of Y are on the original-drawing substrate 21. In this drawing, the zero-order diffraction light figure 48 is an image formed of the transparency section rectilinear-propagation light of the original-drawing substrate 21, and is in agreement with the diffraction light figure made when the original-drawing substrate 21 is removed, or when the transparent original-drawing substrate 21 anything does not have a pattern is used. In addition, a sign 49 shows the edge of an aperture diaphragm 27.
[0033] + The primary diffraction light figure 50 and the -primary diffraction light figure 51 are made in the position according to the line on the original-drawing substrate 21, and the spatial frequency of a space pattern. Drawing 14 (a), drawing 14 (b), and drawing 14 (c) show the difference of the formation position of the +primary diffraction light figure 50 and the -primary diffraction light figure 51 of as it becomes the frequency between altitude from the frequency between low altitudes at order. The distance from the center of an aperture diaphragm 27 to the center of the +primary diffraction light figure 50 and the -primary diffraction light figure 51 is proportional to the line on the original-drawing substrate 21, and the spatial frequency of a space pattern.
[0034] And when the spatial frequency converted into the imprint size to the exposed substrate 26 top is NA/lambda, i.e., line width of face, and space width of face is NA lambda/2, as shown in drawing 14 (b), the center of the +primary diffraction light figure 50 and the -primary diffraction light figure 51 comes on the edge 49 of an aperture diaphragm 27 (not shown in drawing 14) exactly. that such annulus ring lighting demonstrates an effect is a field of quantity spatial frequency where the center of the +primary diffraction light figure 50 and the -primary diffraction light figure 51 comes outside the edge 49 of an aperture diaphragm, as shown in drawing 14 (c)
[0035] As shown in drawing 14 (c), the center of the +primary diffraction light figure 50 and the -primary diffraction light figure 51 In the case of the frequency pattern between altitude which comes out out of the edge 49 of an aperture diaphragm 27, there is 1/2 or less into an aperture diaphragm, and, as for the +primary diffraction light figure 50 and the -primary diffraction light figure 51, the +primary diffracted light and the -primary diffracted light can pass an aperture diaphragm 1/2 or less, respectively. However, the annulus ring lighting of the rate of the portion which usually has an outer diameter as compared with the case of lighting in the aperture diaphragm to the whole surface product of the +primary diffraction light figure 50 and the -primary diffraction light figure 51 using the equal circular secondary light source is larger.
[0036] That is, in drawing 14 (c), it becomes the relation of the following formulas (7).
(Area of the area/annulus ring of a slash portion)
> {(area of a slash-partial-+-less ground portion)area of a /outer-diameter circle} ... (7)
Therefore, many +primary diffracted lights and -primary diffracted lights can be made to usually contribute to the image formation on the exposed substrate 26 (drawing 12) from the case of lighting with annulus ring lighting. Consequently, the contrast of the image formed on the exposed substrate 26 by annulus ring lighting usually becomes higher than the case of lighting in the field where the above-mentioned spatial frequency is larger than NA/lambda.

[0037] Drawing 15 is the property view usually showing an example [calculated value / of the contrast over spatial frequency / annulus ring lighting] with lighting. A horizontal axis is spatial frequency and a vertical axis is the contrast of a pattern image. Drawing 15 is comparing sigmam =0.55, the annulus ring lighting of deltasigma=0.05, and the usual lighting of sigma=0.6. The outer diameter of both secondary light source is equal. Drawing 15 (a) is annulus ring lighting, and drawing 15 (b) is usually lighting. Although the spatial frequency which contrast stops attaching at all is the same than both drawings, it turns out that the annulus ring lighting is more expensive and a bird clapper, i.e., resolution, goes up the spatial frequency which can secure contrast 0.6 under the conditions of D= 0 - D=1.5z.

[0038] Although the improvement factor of the spatial frequency used as the resolution limit has the few amounts D of defocusing when small, it improves notably on the conditions defocused to some extent. For this reason, if annulus ring lighting is used, a detailed pattern will be formed with the deeper depth of focus. Moreover, the influence which the thickness of a resist has on resolution is explained as follows. In drawing 11 , the contrast of a pattern image and the relation with the inclination angle alpha of a resist pattern side attachment wall were described previously. When a problem is simplified, the inclination angle alpha sticks here according to contrast and it becomes a trapezoid pattern cross section, if thickness t of a resist and product talpha with the inclination angle alpha become 1/2 or more [of the space size of a line and a space pattern], stop [resolving] are clear.

[0039] Therefore, in order to resolve the pattern of this size which it is hard coming to resolve, so that resist thickness t is large, if the inclination angle alpha is fixed, and has the same pattern image contrast, t becomes advantageous [the thinner the smaller one, i.e., resist thickness, one]. The inclination angle alpha of a resist pattern side attachment wall is decided by the property of a resist, and, as for a low resist, change of the inclination angle alpha according [a definition] to the contrast of a pattern image is [the larger resist of an optical absorption] in a large inclination. Therefore, the large resist and large definition of absorption become as advantageous [the one where resist thickness is thinner] as a low resist.

[0040] As shown in previous drawing 15 , to the small pattern of spatial frequency, the contrast of the lighting is usually more expensive. Moreover, if sigma is small as shown in drawing 13 , the contrast in a small spatial-frequency field will become still higher. Therefore, in such a field, the good pattern of the cross-section configuration with the lighting usually larger [the inclination angle alpha] to which the direction of lighting made sigma small especially can usually be formed. on the other hand -- annulus ring lighting -- the resolution limit -- the pattern of last-minute contrast is imprinted by the thin resist to a more detailed size

[0041]

[Problem(s) to be Solved by the Invention] As shown above, in the above-mentioned frequency region between altitude which can improve contrast with annulus ring lighting, the +primary diffracted light and the -primary diffracted light can pass an aperture diaphragm 27 1/2 or less, respectively. And the amount which can be passed decreases, so that the line on the original-drawing substrate 21 and the spatial frequency of a space pattern become large. Thus, an improvement factor is not so remarkable, although contrast of the image formed on the exposed substrate 26 can be made larger than the case of the circular secondary light source, if the secondary light source in a circle is used from the passage rate of the +primary diffracted light and the -primary diffracted light being low.

[0042] And up to the hit where the above-mentioned spatial frequency is slightly larger than NA/lambda, although the contrast of a pattern image becomes about 0.6, it will be dwindled or less to 0.6 with increase of spatial frequency. However, g line (wavelength of 436nm) by the present mercury lamp and i line (wavelength of 365nm), The resist for projection exposure which uses a KrF excimer laser (wavelength of 248nm), an ArF excimer laser (wavelength of 193nm), etc. as the primary light source When thickness is set to about 0.5-1.2 micrometers which is anticipated-use thickness, unless the contrast of the image formed on the aforementioned high exposed substrate 26 has 0.6 or more in general, it cannot resolve a pattern by the case of a resist [****], either.

[0043] moreover, pattern formation can be carried out by such about 0.6 contrast -- high -- it is made for the light exposure of a near portion and the basic component near the exposed substrate 26 to have become as the same as possible on the surface of the resist, and enables it to have exposed the resist [****] to as thick a resist as possible That is, in the object for g lines, and the resist for i lines, it has made as [increase / greatly / low resist permeability / by exposure] at the time of an exposure start, and resist permeability is enlarged from the beginning in the object for KrF excimer lasers, and the object for ArF excimer lasers.

[0044] For this reason, when a pattern is formed, even if the inclination angle alpha of a side attachment wall makes resist thickness thin in near and the above-mentioned range at about 80 degrees or more and a perpendicular, most contrast of the pattern image which can be resolved is not changed. Therefore, resist thickness was not able to be made thin and the resolution limit has not been improved notably. When resist thickness was made still thinner, the influence of reflective from an exposed substrate arose notably, and it was impossible and to form a good pattern.

[0045] It is amplitude increase of the 1st standing wave of the influence of reflective. It is a standing wave that an exposure beam of light interferes each other with the reflected ray from the front face of the exposed substrate 26, and produces periodically by turns the position where optical intensity is strong, and a weak position in the thickness direction of a resist. If the transparency of a resist increases, the amplitude of the reflected light will become large, as a result the amplitude of a standing wave will become large. And if resist thickness is made thin, since attenuation until an exposure beam of light reaches the exposed substrate 26 will decrease, the reflected light becomes strong further, and the influence of a standing wave becomes large further.

[0046] Drawing 16 is the cross section showing the influence of the pattern formation on the standing wave. In this drawing, 52 and 53 are the resist patterns formed on the exposed substrate 26. And drawing 16 (a) shows the case where a resist is thick and a standing wave amplitude is small, and drawing 16 (b) shows the case where a resist is thin and a standing wave amplitude is large. Although a pattern will be made if a resist is thick and a standing wave amplitude is small, a pattern cannot be imprinted, if a resist becomes thin and a standing wave amplitude becomes above to some extent. In the case of drawing 16 (b), the resist cross-section configuration shown with the dashed line 54 is a configuration which should originally be imprinted.

[0047] In addition, cycle length t0 of the optical intensity distribution which change in the period of a standing wave, i.e., the thickness direction of a resist, It is shown by the following formulas (8).

t0 =lambda / 2n ... (8)

[0048] Next, there is excessive exposure of the shading section by the reflected light from an exposed substrate as the 2nd of the influence of reflective. Drawing 17 is the cross section showing the influence of the reflected light from an exposed substrate, and how depending on which the beam-of-light group which carries out image formation of the pattern image progresses in the center of the thickness of the resist 54 on the exposed substrate 26 is shown. As for the original resist pattern latent image to need, i.e., the profile of the portion which should originally be exposed, and 56-64, in this drawing, a dashed line 55 shows an exposure beam of light. The relation which the incident angle range of the exposure beam of light which irradiates the exposed substrate 26 is decided by the numerical aperture NA of a projection optical system 25, and shows the maximum angle of inclination of an exposure beam of light by theta, then the following formulas (9) is realized.

Theta=sin-1NA ... (9)

[0049] If a resist is transparent and the reflection factor of the exposure beam of light in the front face of the exposed substrate 26 is high, the exposure beam of light 58 which carried out incidence at the large angle, and 62 grades will expose the adjoining shading section too much. In the latest projection aligner with the large numerical aperture NA of a projection optical system 25, since an angle theta serves as size, excessive exposure of the contiguity shading section becomes remarkable. Moreover, if resist thickness is made thin, since attenuation of intensity until an exposure beam of light arrives at the front face of the exposed substrate 26 will decrease, from the thick time, the strong reflected light will return from the exposed substrate 26 into a resist, and the contiguity shading section will be exposed too much more notably.

[0050] As explained above, in the Prior art, unless the contrast of a pattern image had about 0.6 or more, it did not resolve, but the resolution limit spatial frequency in that case was as being shown in drawing 18 . Drawing 18 shows the resolution limit spatial frequency from which the contrast over parameter sigmam which determines lighting conditions, and deltasigma is set to 0.6 with the contour line. In drawing 18 , the lighting conditions that the numeric value of resolution limit spatial frequency is larger serve as high resolving. The unit of spatial frequency is NA/lambda and one half of the inverse numbers of the spatial frequency in drawing 18 becomes a resolution. Moreover, the line of slant upward slanting to the right used as sigmam ≑deltasigma in drawing 18 is usually equivalent to lighting, and others are the conditions of annulus ring lighting.

[0051] The conditions of the formula (10) of the following [lower right / line / across **] are shown.

sigmaout =sigmam+deltasigma=1.0 ... (10)

[0052] It is performed as follows in order to obtain the topographic contour plot [like] shown in drawing 18 . First, it asks for the relation of spatial frequency and contrast as shown in drawing 15 from very much sigmam and the combination of deltasigma. Subsequently, it asks for the spatial frequency of the intersection of the horizontal line and the contrast curve of each defocusing conditions showing contrast 0.6 as resolution limit spatial frequency. And the point of the lighting conditions used as the same resolution limit spatial frequency is put in a row.

[0053] The resolution limit spatial frequency in amount of defocusing D=1.5z (being here z=lambda/2 NA2) considered that drawing 18 (b) can secure the practical depth of focus is shown. If this amount of defocusing compares and deltasigma will be made small, using lighting conditions as sigmam =0.5-0.6, resolution limit spatial frequency will improve to some extent. However, as shown in drawing 18 (a), it improves only at most about several% also as sigmam =0.39-0.53 to which high resolving is expected most, the resolution limit spatial frequency, i.e., highest resolution limit, in a focusing point position (the amount D= 0 of defocusing). That is, although the depth of focus improves remarkable, improvements of the highest resolution are few.

[0054] In addition, it is better to carry out to 0.15 or less in general, since the value of deltasigma became high resolving so that it was small. Moreover, if deltasigma is made into less than 0.05 small value, the lighting homogeneity in the exposure field will deteriorate, an exposure side illuminance will become small, the edge of a pattern will deteriorate, or the pattern in the edge of the pattern aggregate will deteriorate. Therefore, about [which becomes high resolving and the above-mentioned problem does not produce notably] deltasigma=0.05-0.15 is good.

[0055] This invention is made in order to cancel the above troubles, and it aims at enabling it to form a more detailed pattern.

[0056]

[Means for Solving the Problem] The secondary light source in a circle which irradiates the light of wavelength lambda with which the projection exposure method of this invention fabricated the portion with strong optical intensity in a circle at an original-drawing substrate, By the projection aligner which has the projection optical system which projects the pattern on an original-drawing substrate on an exposed substrate, and forms the image of a pattern on an exposed substrate In the projection exposure method that expose in the projected projection light and a refractive index imprints the pattern on an original-drawing substrate to a resist using the resist of n, it is performed as follows. First, the average of the partial coherence

factor corresponding to the circular secondary light source which has a diameter equal to the outer diameter of the secondary light source in a circle, and the partial coherence factor corresponding to the circular secondary light source which has a diameter equal to the bore of the secondary light source in a circle is made or less [0.61 or more] into 0.73. Moreover, let one half of the differences of the partial coherence factor corresponding to the circular secondary light source which has a diameter equal to the outer diameter of the secondary light source in a circle, and the partial coherence factor corresponding to the circular secondary light source which has a diameter equal to the bore of the secondary light source in a circle be or more 0.05 0.15 or less value. And the reflection factor of the projection light from an exposed substrate was made 5% or less, the resist film was formed in the thickness of 3 and lambda / (2n) following, projection exposure is carried out at a resist film, and the pattern on an original-drawing substrate was imprinted. Thus, if a very thin resist layer is first formed on an antireflection film, since the influence of reflective from an exposed substrate will be lost, contrast can also imprint the image of only about 0.4 patterns to a resist pattern. And even the pattern of the highest spatial frequency can form [contrast] the pattern image of about 0.4 on an exposed substrate by using the secondary light source in a circle made above in the range which can secure the practical depth of focus.

[0057] Moreover, the average of the partial coherence factor corresponding to the circular secondary light source which has a diameter equal to the outer diameter of the secondary light source in a circle by one side, and the partial coherence factor corresponding to the circular secondary light source which has a diameter equal to the bore of the secondary light source in a circle is made or more into 0.73. In addition, the partial coherence factor corresponding to the circular secondary light source which has a diameter equal to the outer diameter of the secondary light source in a circle is made or less into 0.95, and let one half of the differences of the partial coherence factor corresponding to the circular secondary light source which has a diameter equal to the outer diameter of the secondary light source in a circle, and the partial coherence factor corresponding to the circular secondary light source which has a diameter equal to the bore of the secondary light source in a circle be or more 0.05 0.15 or less value. And the reflection factor of the projection light from an exposed substrate was made 5% or less, and a resist film is formed in the thickness of 3 and lambda / (2n) following, and it was made to carry out projection exposure of the pattern image which passed the original-drawing substrate on the exposed substrate. Consequently, even the pattern of the highest possible spatial frequency can form by using the secondary light source in a circle made above.

[0058]

[Embodiments of the Invention] The gestalt of implementation of this invention is explained with reference to drawing below. In the gestalt of this operation, the reticle in which the line and space pattern of various sizes of a line pair space were formed was used as an original-drawing substrate. [of a ratio 1:1] The line section was formed with chromium and used the quartz substrate as a base of a reticle. Moreover, the silicon wafer was used as an exposed substrate. A line and a space pattern are 12 lines in the transparency section, and a pattern which consists of 11 spaces.

[0059] As shown in drawing 1 , the silicon wafer 1 which imprints a pattern places the front face 2 first into the nitrogen gas which mixed the steam of a surfactant hexamethyldisilazane (HMDS), and activates a front face 2. Subsequently, the spin coat of the antireflection film SWK by TOKYO OHKA KOGYO CO., LTD. is carried out, it, and the antireflection film 3 of about 0.2-micrometer thickness is formed. SWK is indicated by reference 4 (from the 295th page to SPIE Vol.631 Advances in Resist Technology and Processing III (1986) and 301 pages), it is compounded from the high molecular compound which makes the derivative of triazine a principal component, and coloring matter is added.

[0060] The effect of the antireflection films 3, such as SWK mentioned above, is correlated with the thickness. Drawing 2 is the correlation diagram showing the relation between the line breadth of the line formed and a space pattern, and the thickness of an antireflection film 3. This has the reduction projection exposure system of NA=0.57, is the reduction projection aligner using i line as the light source, and is abbreviation t0 about a 0.22-micrometer line and a space pattern. Projection exposure is carried out at the resist of thickness. Moreover, sigmam =0.63 and the secondary light source of deltasigma=0.07 in a circle were used at this time.

[0061] Setting to this drawing, a horizontal axis is na about the refractive index of an antireflection film 3. When carrying out, it is the thickness of the antireflection film 3 standardized by ta =lambda/(2na). In addition, lambda is the wavelength of an exposure beam of light, and is 365nm in this case. moreover, a black rectangular head -- light exposure -- 160 mJ/cm2 and a white rectangular head -- light exposure -- 165 mJ/cm2 and a black dot -- light exposure -- 170 mJ/cm2 and a white round head -- light exposure -- 175 mJ/cm2 it is .

[0062] In the place of the thickness 0 of the antireflection film 3 which does not use the antireflection film, pattern line breadth is 0.44 micrometers, it is with a design value [of 0.22 micrometers] twice, namely, not resolving is shown so that clearly from this drawing. And the line breadth of the pattern imprinted is a damping coefficient ka in addition to the thickness and the refractive index of an antireflection film 3. Although it depends, it is ta in general. It changes to a period. It is ta when using this antireflection film 3 from this result. It is shown that it is or more about 1.25 need.

[0063] On the other hand, drawing 3 is the property view showing the relation between the thickness of an antireflection film 3, and the reflection factor of the exposure beam of light by existence of this antireflection film 3. The antireflection film 3 is formed on the silicon wafer 1 by which the mirror finish is carried out. If this drawing 3 is compared with aforementioned drawing 2 and light exposure will be adjusted in drawing 2 , the thickness of the antireflection film 3 from which the imprint pattern line breadth near design line breadth is obtained corresponds to the thickness range of the reflection factor prevention film with which the reflection factor of an exposure beam of light becomes 5% or less in drawing 3 . Therefore, what is necessary is just to form an antireflection film 3 so that a reflection factor may become 5% or less.

[0064] Moreover, they are about 1.25 ta(s) about the thickness of the antireflection film 3 of absorptivity from drawing 2 . If it is the above, change of the line pattern line breadth imprinted will become **20 - 25% or less to the thickness beyond it. Moreover, the change of line pattern line breadth to change of the thickness of an antireflection film 3 becomes quiet. Generally the allowed value of the error of pattern line breadth is about **10%. Therefore, when the above-mentioned imprint line breadth forms this antireflection film for the purpose of the thickness, then the predetermined thickness of the antireflection film 3 of a field which changes quietly, even if there are some variation in process conditions, such as temperature, resist viscosity, and light exposure, and thickness unevenness of an antireflection film 3, it can consider as the inside of the practical tolerance which mentioned change of pattern line breadth above. Therefore, they are about 1.25 ta(s) about thickness. If it considers as the above, in addition, it is good. If the thickness of an antireflection film is standardized as mentioned above even if the thickness of the refractive index, damping coefficient, and resist of an antireflection film differs, the situation of imprint line breadth is the same as that of drawing 2 .

[0065] And on this antireflection film 3, the spin coat of high resolution i line positive type resist THMR-iP3300 by TOKYO OHKA KOGYO CO., LTD. was carried out, it, and about 0.2 to about 1.1 micrometers resist film 4 was formed. What is necessary is just to make the resist film 4 more than more than into the thickness, for example, 0.05 micrometers, which can be formed. This resist is typical i line positive type resist which uses the resin of a novolak system as a base resin. A refractive index is the cycle length t0 of a standing wave [as opposed to / are 1.68 and / i line]. It is 0.1086 micrometers.

[0066] The line and space pattern on the original-drawing substrate mentioned above on the silicon wafer 1 shown above using the projection aligner shown by drawing 9 and drawing 12 are imprinted. Here, i line 1 / 5 reduction projection RENZU ** of NA=0.57 were used as a projection optical system 25 of this drawing 9 . And it considered as sigmaout =0.70 and the annulus ring lighting of sigmain=0.56 (sigmam =0.63, deltasigma=0.07) as the secondary light source using the light source of an annulus ring configuration as shown in drawing 4 . In drawing 4 , they are the portion into which the white section 5 injects light, and the portion into which the slash section 6 does not inject light. moreover, only the evaluation pattern section of about 3mm of a reticle around mostly formed in the center is exposed -- as -- a reticle blind -- applying -- light exposure and a focal position -- the inside of one wafer -- the shape of a matrix -- various **** -- it exposed

[0067] On the other hand, in order to measure resolution, it exposed by completely making other conditions the same also with the case where lighting is considered as the usual lighting of sigma=0.6. After exposing and performing BEKU, negatives were developed in tetramethylammonium hydroxide (TMAH) 2.38% solution, and pure water performed the rinse. Next, the profile of the resist pattern imprinted on the silicon wafer 1 was observed with the scanning electron microscope, and the imprint line breadth of the line pattern of a line and a space pattern center section was evaluated. Bearing in mind that the ratio of the line pair space of a reticle is 1:1, it investigated on the light exposure conditions from which the average line pattern width of face of a line and a space pattern center section turns into expected pattern width of face most closely, the highest resolving pattern size, i.e., the resolution, when making a focal position into an optimum value.

[0068] Drawing 5 is the property view showing the change of the highest resolving pattern size when changing lighting conditions and resist thickness. In this drawing, a horizontal axis shows the pattern size of the 1 to 1 line and the space pattern which resist thickness and the vertical axis could resolve. the time of standardizing the thickness of the resist film 4 (drawing 1) by t0 =lambda used as the generating period of a standing wave / 2n -- resist thickness -- 10t0 -5t0 it is -- the grades of an improvement are few, although resolution will usually be improved from lighting (characteristic curve 102), if annulus ring lighting (characteristic curve 101) is used for a case Moreover, in this resist thickness range, even if it makes resist thickness thin, resolution seldom improves. On the other hand, annulus ring lighting is used and it is the thickness of a resist 3t 0 If it carries out to below a grade, as shown in the characteristic curve 101 of drawing 5 , resolution will improve very notably.

[0069] Drawing 6 is the property view showing the relation of the previous spatial frequency and previous contrast in sigmam =0.63 and the annulus ring lighting conditions which become deltasigma=0.07. A horizontal axis is spatial frequency and a vertical axis is the contrast of a pattern image. Moreover, D is the amount of defocusing, and z=lambda/NA 2. It sets to an experiment and is the thickness of a resist about 2t 0 The highest resolving pattern size of the annulus ring lighting when carrying out was 0.23 micrometers - 0.22 micrometers. It is shown by the following formulas (11) when it converts into the spatial frequency equivalent to the resolution limit.

1/(0.44-0.46 micrometers) =1.456-1.392 (NA/lambda) ... (11)

[0070] When drawing 6 is referred to, contrast will resolve resolving the pattern of the above-mentioned spatial frequency about by about 0.4. That is, an antireflection film is given and it is resist thickness 2t 0 By carrying out, the contrast of a pattern image can imprint a pattern also on about 0.4 conditions. Since the pattern resolution limit changes with resist thickness, although resolvable contrast also changes little by little with resist thickness, resist thickness is 0 about 3t. In the following ranges, the contrast of a pattern image can form a pattern the condition before and behind 0.4 in general. Thereby, the improvement in large of the above-mentioned resolution is attained.

[0071] By the conventional projection exposure method which is not resolved in a pattern image unless contrast has 0.6 or more, even if it adopted annulus ring lighting, the small deer improvement of the highest resolution in a focusing point position was not carried out. On the other hand, according to the gestalt of this operation, as mentioned above, the highest resolution in a focusing point position is also improved sharply.

[0072] This reason is explained using the calculation result of contrast. If a pattern can be formed before and behind contrast 0.4, convenience will become good extremely at annulus ring lighting. Drawing 7 calculates the spatial frequency which can secure contrast 0.4 when the amounts D of defocusing are 0 and 1.5z to various lighting conditions, and is sigmam.

Resolution limit spatial frequency is shown in contour line by setting a vertical axis as a horizontal axis and deltasigma. The unit of spatial frequency is NA/lambda and one half of the inverse numbers of the spatial frequency in drawing 7 becomes a resolution. Moreover, the line across sigmam =deltasigma in drawing 7 is usually equivalent to lighting, and others are the conditions of annulus ring lighting. As for the straight line across **, the lower right shows the conditions of a previous formula (10).

[0073] Below, as drawing 7 was shown below, it was obtained. First, it asks for the relation of spatial frequency and contrast as shown in drawing 6 from very much sigmam and the combination of deltasigma. Subsequently, it asks for the spatial frequency of the intersection of the horizontal line and the contrast curve of each defocusing conditions showing contrast 0.4 as resolution limit spatial frequency. And the point of the lighting conditions used as the same resolution limit spatial frequency was put in a row.

[0074] the pattern contrast of the former [spatial frequency / resolution limit / case / of D=1.5z of drawing 7 (b) / the case of D= 0 of drawing 7 (a), and] -- 0.6 -- it becomes high by leaps and bounds from the resolution limit spatial frequency shown in drawing 18 in the case of being required Although the resolution limit spatial frequency in D= 0 corresponds to the highest resolution, the resolution limit spatial frequency is sigmam from drawing 7 (a). It becomes so high that it is large. Moreover, the resolution limit spatial frequency in the case of being amount of defocusing D=1.5z considered that the practical depth of focus is securable becomes the largest among sigmam =0.61-0.73 from drawing 7 (b).

[0075] However, it was referred to as deltasigma=0.05-0.15. It is better to make deltasigma or less into 0.15 in general, since it became high resolving so that deltasigma was small. On the other hand, if deltasigma is too small, the lighting homogeneity in the exposure field will deteriorate, an exposure side illuminance will become small, the edge of a pattern will deteriorate, or the pattern in the edge of the pattern aggregate will deteriorate. Therefore, deltasigma>=0.05 which these problems do not produce notably are good. That is, the following formulas 12 show the proper range of deltasigma.

0.05 <=deltasigma<=0.15 ... (12)

[0076] Thus, considering practical use, suitable lighting conditions serve as the range of the slash field of drawing 7 (b). The conditions used in the above-mentioned experiment are also in this range, and the annulus ring lighting conditions of the 1st term of a patent claim are conditions which can do resolution most highly in the range which can secure this practical depth of focus.

[0077] On the other hand, it will be sigmam if only the highest resolution is made high. Although it is so good that it is large, if not much large, a pattern stops resolving by slight defocusing, and it is not realistic. Therefore, it is better to have made it [sigmaout =sigmam+deltasigma] become 0.95 or less in general. The ring lighting conditions of the 2nd **** of a patent claim correspond to this. In addition, since the value of deltasigma is the same as that of the above, about deltasigma=0.05-0.15 is good.

[0078] [sigmaout =sigmam+deltasigma] Even when it is D=1.5z which can secure <0.95, then the practical depth of focus, it is larger than the resolution limit spatial frequency in the usual lighting which resolution limit spatial frequency showed to drawing 18 (b). That is, in drawing 18 (b), although the resolution limit spatial frequency of lighting is usually about 0.65 at the maximum, in drawing 7 (b), about 0.65 or more are [sigmaout =sigmam+deltasigma] <0.95 and deltasigma=0.05-0.15, then the resolution limit spatial frequency. After all, in order to make the highest resolution as high as possible, the conditions of the range of the slash field of drawing 7 (a) are the optimal.

[0079] When contrast resolves only to 0.6, in order to make resolution the highest in the range which can secure the practical depth of focus, sigmam =0.5-0.6 are more desirable than drawing 18 (b). Moreover, even if it cannot take the depth of focus, for obtaining the highest resolution, sigmam =0.39-0.53 are more desirable than drawing 18 (a). Such sigmam The conditions shown in drawing 7 differ and conditions are the above-mentioned sigmam. Conditions are conditions peculiar to this invention. In addition, the resolution limit spatial frequency shown in drawing 7 and drawing 18 shows the spatial frequency which contrast can secure 0.4 or 0.6 to the pattern with all the spatial frequency below the spatial frequency.

[0080] Although superimposed on various spatial-frequency components in the case of the common pattern of an arbitrary configuration, if it is more than the size with which the lower limit of a pattern is equivalent to the pattern width of face of the 1 to 1 line and the space pattern of the resolution limit spatial frequency, it will resolve mostly. Moreover, in the state where there is no antireflection film 3 although the antireflection film 3 was applied to the bottom of the resist film 4 in the above-mentioned example, it is the thickness of the resist film 4 3t 0 If it is made the following thin thickness, a detailed pattern will hardly be resolved. Annulus ring lighting and the pattern size to which a line and a space pattern usually resolve which case of lighting to 1 to 1 were larger sizes than 0.6 micrometers.

[0081] In addition, although the antireflection film SWK used in the above-mentioned example is the material containing the coloring matter of extinction nature, since the exposure beam of light generally used for projection exposure is the homogeneous light or a quite small light of wavelength distribution width of face, it can expect the same effect also by the film by which reflection is prevented by multilayer interference. In addition, what is necessary is just to make a reflection factor into 5% or less in general, when carrying out acid resisting by multilayer interference, as mentioned above. Moreover, the data shown in drawing 5 - drawing 7 are the periodic size t0 of the standing wave with which standardize spatial frequency and the amount of defocusing by the theoretical standard value which combined the exposure wavelength lambda and the numerical aperture NA of a projection optical system 25, and it is decided with the exposure wavelength lambda and the resist refractive index n that resist thickness will also be. It is standardized and shown. Therefore, it is thought that it can apply when the refractive indexes n of a resist differ, even if the exposure wavelength lambda and the numerical aperture NA of a

projection optical system 25 change.

[0082] Moreover, if the configuration of the secondary light source of annulus ring lighting is a false annulus ring configuration almost near an annulus ring as shown in drawing 8 (a) - (d) even if it is not the perfect annulus ring shown in drawing 4 , it is clear. [where the same effect is expectable] sigmam and deltasigmam What is necessary is just to assume the annulus ring which approximates the shape of these false annulus rings, in order to think. They are the portion into which the white section injects light, and the portion into which the slash section does not inject light like [drawing 8] drawing 4 . In addition, permeability is high to part arbitration nearly for a periphery, and it is made for permeability to become low by the center section, as the permeability of the white portion of drawing 8 (d) is shown in drawing 8 (e).

[0083]

[Effect of the Invention] As explained above, in this invention, the reflection factor of the projection light from an exposed substrate is made into 0.5% or less by being with ** antireflection film etc., ** 3t0 It combined using using the following very thin resists, **0.61 <=sigmam <=0.73, 0.05 <=deltasigma<=0.15 or sigmam >0.73, sigmaout <=0.95, and the secondary light source of 0.05 <=deltasigma<=0.15 in a circle. Consequently, on an exposed substrate, the pattern image to the frequency between altitude can be made from the low contrast of about 0.4, and a resist pattern can be formed based on it. having combined any above two or less by this according to this invention -- if -- it cannot reach -- high -- it has the effect that a pattern imprint [****] can be performed By this, large detailed-ization of a semiconductor device, an integrated circuit, a diffraction grating, a DFB laser, etc. can be attained.

[Translation done.]

CLAIMS

[Claim(s)]

[Claim 1] The secondary light source in a circle which irradiates the light of the wavelength lambda which fabricated the portion with strong optical intensity in a circle at an original-drawing substrate. The projection optical system which projects the pattern on the aforementioned original-drawing substrate on an exposed substrate, and forms the image of the aforementioned pattern on an exposed substrate. The partial coherence factor corresponding to the circular secondary light source which is the projection exposure method equipped with the above, and has a diameter equal to the outer diameter of the aforementioned secondary light source in a circle, The average with the partial coherence factor corresponding to the circular secondary light source which has a diameter equal to the bore of the aforementioned secondary light source in a circle is made or less [0.61 or more] into 0.73. The partial coherence factor corresponding to the circular secondary light source which has a diameter equal to the outer diameter of the aforementioned secondary light source in a circle, One half of differences with the partial coherence factor corresponding to the circular secondary light source which has a diameter equal to the bore of the aforementioned secondary light source in a circle is made into or more 0.05 0.15 or less value. The reflection factor of the aforementioned projection light from the aforementioned exposed substrate is made 5% or less, and the aforementioned resist film is formed in the thickness of 3 and lambda / (2n) following, and it is characterized by carrying out projection exposure and imprinting the pattern on the aforementioned original-drawing substrate on the aforementioned resist film.

[Claim 2] The secondary light source in a circle which irradiates the light of the wavelength lambda which fabricated the portion with strong optical intensity in a circle at an original-drawing substrate. The projection optical system which projects the pattern on the aforementioned original-drawing substrate on an exposed substrate, and forms the image of the aforementioned pattern on an exposed substrate. The partial coherence factor corresponding to the circular secondary light source which is the projection exposure method equipped with the above, and has a diameter equal to the outer diameter of the aforementioned secondary light source in a circle, The average with the partial coherence factor corresponding to the circular secondary light source which has a diameter equal to the bore of the aforementioned secondary light source in a circle is made or more into 0.73. The partial coherence factor corresponding to the circular secondary light source which makes 0.95 or less the partial coherence factor corresponding to the circular secondary light source which has a diameter equal to the outer diameter of the aforementioned secondary light source in a circle, and has a diameter equal to the outer diameter of the aforementioned secondary light source in a circle, One half of differences with the partial coherence factor corresponding to the circular secondary light source which has a diameter equal to the bore of the aforementioned secondary light source in a circle is made into or more 0.05 0.15 or less value. The reflection factor of the aforementioned projection light from the aforementioned exposed substrate is made 5% or less, and the aforementioned resist film is formed in the thickness of 3 and lambda / (2n) following, and it is characterized by carrying out projection exposure and imprinting the pattern on the aforementioned original-drawing substrate on the aforementioned resist film.

[Claim 3] The projection exposure method characterized by making the reflection factor of the projection light from the aforementioned exposed substrate into 5% or less by forming an absorbed type antireflection film in the projection exposure method according to claim 1 or 2.

[Translation done.]